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(54) **PIGMENT PROTEIN**

(57) An object of the present invention is to provide a novel chromoprotein derived from *Cnidopus japonicus*. The present invention provides a chromoprotein derived from *Cnidopus japonicus* having the following properties:

- (1) the absorption maximum wavelength is 559 nm and the fluorescence maximum wavelength is of 578 nm;
(2) the molar absorption coefficient is 61,150 at 559

- nm;
(3) the quantum yield is less than 0.01; and
(4) the pH sensitivity of light-absorbing properties is stable at between pH 4 and pH 10.

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Description

TECHNICAL FIELD

5 [0001] The present invention relates to a novel chromoprotein. More specifically, the present invention relates to a novel chromoprotein derived from *Cnidopus japonicus*, and the use thereof.

BACKGROUND ART

10 [0002] Green fluorescent protein (GFP) derived from *Aequorea victoria*, a jellyfish, has many purposes in biological systems. Recently, various GFP mutants have been produced based on the random mutagenesis and semi-rational mutagenesis, wherein a color is changed, a folding property is improved, luminance is enhanced, or pH sensitivity is modified. Fluorescent proteins such as GFP are fused with other proteins by gene recombinant technique, and monitoring of the expression and transportation of the fusion proteins is carried out.

15 [0003] One of the most commonly used types of GFP mutant is Yellow fluorescent protein (YFP). Among *Aequorea*-derived GFP mutants, YFP exhibits the fluorescence with the longest wavelength. The values ϵ and Φ of the majority of YFPs are 60,000 to 100,000 M⁻¹ cm⁻¹ and 0.6 to 0.8, respectively (Tsien, R. Y. (1998). Ann. Rev. Biochem. 67, 509-544). These values are comparable to those of the general fluorescent group (fluorescein, rhodamine, etc.). Accordingly, improvement of the absolute luminance of YFP is nearly approaching its limit.

20 [0004] In addition, cyan fluorescent protein (CFP) is another example of the GFP mutant. Of this type of protein, ECFP (enhanced cyan fluorescent protein) has been known. Moreover, red fluorescent protein (RFP) has been isolated from sea anemone (*Discosoma sp.*). Of this type of protein, DasRed has been known. Thus, 4 types of fluorescent proteins, that are, green fluorescent protein, yellow fluorescent protein, cyan fluorescent protein, and red fluorescent protein, have successively been developed. The range of the spectrum has significantly been expanded.

DISCLOSURE OF THE INVENTION

[0005] An object of the present invention is to provide a novel chromoprotein derived from *Cnidopus japonicus*.

30 [0006] The present inventors have conducted intensive studies directed towards achieving the aforementioned object. They have designed suitable primers based on information regarding the amino acid sequences of known fluorescent proteins. Using these primers, they have succeeded in the amplification and cloning of a gene encoding a novel chromoprotein from the cDNA library of *Cnidopus japonicus* exhibiting a green color. The present inventors have further analyzed the light-absorbing properties and pH sensitivity of the obtained chromoprotein derived from *Cnidopus japonicus*. The present invention has been completed based on these findings.

35 [0007] That is to say, the present invention provides a chromoprotein derived from *Cnidopus japonicus* having the following properties:

- (1) the absorption maximum wavelength is 559 nm and the fluorescence maximum wavelength is of 578 nm;
- (2) the molar absorption coefficient is 61,150 at 559 nm;
- 40 (3) the quantum yield is less than 0.01; and
- (4) the pH sensitivity of light-absorbing properties is stable at between pH 4 and pH 10.

[0008] In another aspect, the present invention provides a chromoprotein having either one of the following amino acid sequences:

- (a) the amino acid sequence shown in SEQ ID NO: 1; and
- (b) an amino acid sequence comprising a deletion, substitution and/or addition of one or several amino acids with respect to the amino acid sequence shown in SEQ ID NO: 1, and having light-absorbing properties.

50 [0009] In another aspect, the present invention provides DNA encoding the protein of the present invention.

[0010] In another aspect, the present invention provides either one of the following DNAs:

- (a) DNA encoding the amino acid sequence shown in SEQ ID NO: 1; and
- (b) DNA encoding an amino acid sequence, which comprises a deletion, substitution and/or addition of one or several amino acids with respect to the amino acid sequence shown in SEQ ID NO: 1, and has light-absorbing properties.

[0011] In another aspect, the present invention provides DNA having either one of the following nucleotide sequences:

es:

- (a) the nucleotide sequence shown in SEQ ID NO: 2; and
 (b) a nucleotide sequence comprising a deletion, substitution and/or addition of one or several nucleotides with respect to the nucleotide sequence shown in SEQ ID NO: 2, and encoding a protein having light-absorbing properties.

[0012] In another aspect, the present invention provides a recombinant vector having the DNA of the present invention.

[0013] In another aspect, the present invention provides a transformant having the DNA or recombinant vector of the present invention.

[0014] In another aspect, the present invention provides a fusion protein composed of the chromoprotein of the present invention and another protein.

[0015] In another aspect, the present invention provides a method for analyzing a physiologically active substance, which is characterized in that the FRET (fluorescence resonance energy transfer) method is applied using the chromoprotein of the present invention as an acceptor protein.

[0016] In another aspect, the present invention provides a light-absorbing reagent kit comprising the chromoprotein, DNA, recombinant vector, transformant, or fusion protein of the present invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[0017]

Figure 1 shows the results obtained by measuring the absorption spectrum of the chromoprotein (KP) derived from *Cnidopus japonicus* of the present invention. The transverse axis indicates the wavelength of absorbed light, and the vertical axis indicates absorbance.

Figure 2 shows the pH sensitivity of the absorption spectrum of the chromoprotein (KP) derived from *Cnidopus japonicus* of the present invention. The transverse axis indicates pH value, and the vertical axis indicates absorbance. 559 nm indicates the absorbance that is specific to the chromoprotein (KP) derived from *Cnidopus japonicus* of the present invention, and 275 nm indicates the absorbance (light absorption by aromatic amino acids) that is generally used as a quantitative amount of protein. In other words, it is shown that the amount of protein is constant at 275 nm, and the absorbance at 559 nm that is specific to the chromoprotein (KP) derived from *Cnidopus japonicus* of the present invention hardly changes in the range between pH 4 and pH 10.

Figure 3 shows the fluorescence spectrum of the chromoprotein (KP) derived from *Cnidopus japonicus* of the present invention. The transverse axis indicates wavelength, and the vertical axis indicates fluorescence intensity. The term "em" indicates a fluorescence spectrum, and the term "ex" indicates an excitation spectrum.

BEST MODE FOR CARRYING OUT THE INVENTION

[0018] The embodiments of the present invention will be described in detail below.

(1) Chromoprotein of the present invention

[0019] The chromoprotein of the present invention is characterized in that it is derived from *Cnidopus japonicus*, and has the following properties:

- (1) the absorption maximum wavelength is 559 nm and the fluorescence maximum wavelength is of 578 nm;
- (2) the molar absorption coefficient is 61,150 at 559 nm;
- (3) the quantum yield is less than 0.01; and
- (4) the pH sensitivity of light-absorbing properties is stable at between pH 4 and pH 10.

[0020] *Cnidopus japonicus* is one type of sea anemone belonging to Anthozoa of Cnidaria. Among the types of sea anemone that can be seen in Japan, *Cnidopus japonicus* has the highest degree of color mutation. Its withers height is always low, and it has a large number of warts on the body wall thereof. It has approximately 200 short tentacles. A parent sea anemone discharges developed embryos from its oral part. The discharged embryos become attached to the body wall of the parent sea anemone. Thereafter, the embryos are further developed, and as a result, they become baby sea anemone. Thus, this sea anemone was named *Komochi Isoginchaku* (a Japanese name meaning "seed sea anemone"). This type of sea anemone is distributed in the intertidal zones on the rock coasts between Hokkaido and

Boso Peninsula and also in the zones immediately below the intertidal zones.

[0021] It is to be noted that a chromoprotein having the aforementioned properties was isolated using *Cnidopus japonicus* as a starting material in the examples described later, but that the chromoprotein of the present invention may also be obtained from forms of sea anemone other than *Cnidopus japonicus* in some cases. Such a chromoprotein is also included in the scope of the present invention.

[0022] As described in the examples below, the chromoprotein of the present invention has an absorption maximum wavelength of 559 nm and a fluorescence maximum wavelength of 578 nm. In addition, the present chromoprotein has a molar absorption coefficient of 61,150 at 559 nm, and a quantum yield of less than 0.01.

[0023] The molar absorption coefficient represents the amount of absorbed photons per mole of molecule, and the quantum yield represents a numerical value showing the amount of the absorbed photons that can be emitted as fluorescence. Since the chromoprotein of the present invention has a quantum yield of less than 0.01 which is extremely low, the emitted red fluorescence (578nm) is also extremely weak. Due to this property, the chromoprotein of the present invention can be used: (1) as an acceptor molecule (energy receptor) in FRET; (2) in development of a system for converting the energy of applied light into energy other than the light; and (3) in introduction of a mutation into the amino acid sequence of the protein to modify it so that it emits fluorescence.

[0024] In addition, the chromoprotein of the present invention is characterized in that the pH sensitivity of light-absorbing properties is stable at between pH 4 and pH 10. That is to say, in the case of the chromoprotein of the present invention, the peak value of the absorption spectrum does not significantly fluctuate in the range between pH 4 and pH 10. Accordingly, even under the same conditions, the chromoprotein of the present invention can be used in a broad range of pH environments, and thus, the use of the chromoprotein *in vivo* has few restrictions.

[0025] The examples of the chromoprotein of the present invention include a chromoprotein having either one of the following amino acid sequences:

(a) the amino acid sequence shown in SEQ ID NO: 1; and

(b) an amino acid sequence comprising a deletion, substitution and/or addition of one or several amino acids with respect to the amino acid sequence shown in SEQ ID NO: 1, and having light-absorbing properties.

[0026] The scope of "one or several" in the phrase "an amino acid sequence comprising a deletion, substitution and/or addition of one or several amino acids" is not particularly limited in the present specification. For example, it means 1 to 20, preferably 1 to 10, more preferably 1 to 7, further preferably 1 to 5, and particularly preferably 1 to 3.

[0027] The term "light-absorbing properties" is used in the present specification to mean properties capable of absorbing light having a certain wavelength. For example, an absorption maximum wavelength may be 559 nm as in the case of the chromoprotein described in the present specification, or the value of the absorption maximum wavelength may also be shifted. It is preferable that the pH sensitivity of light-absorbing properties is stable at between pH 4 and pH 10.

[0028] The chromoprotein of the present invention having the amino acid sequence shown in SEQ ID NO: 1 in the sequence has a quantum yield of less than 0.01, and emits an extremely weak fluorescence. In the present invention, one or several amino acids are deleted, substituted, and/or added with respect to the amino acid sequence shown in SEQ ID NO: 1, so as to produce a protein having modified light-absorbing properties, or so as to produce a protein emitting stronger fluorescence in some cases. The thus produced proteins are also included in the scope of the present invention.

[0029] The method of obtaining the chromoprotein of the present invention is not particularly limited. The protein may be either a protein synthesized by chemosynthesis, or recombinant protein produced by a gene recombination technique.

[0030] Where a recombinant protein is produced, it is necessary to obtain DNA encoding the protein. Appropriate primers are designed by using information regarding the amino acid sequence shown in SEQ ID NO: 1 of the sequence listing of the present specification and the nucleotide sequence shown in SEQ ID NO: 2 thereof. Using these primers, PCR is carried out by using cDNA library derived from *Cnidopus japonicus* as a template, so that DNA encoding the chromoprotein of the present invention can be obtained. The chromoprotein of the present invention can be produced by introducing this DNA into an appropriate expression system. Expression in an expression system will be described later in the present specification.

(2) DNA of the present invention

[0031] According to the present invention, a gene encoding the chromoprotein of the present invention is provided.

[0032] Specific examples of DNA encoding the chromoprotein of the present invention may include either one of the following DNAs:

- (a) DNA encoding the amino acid sequence shown in SEQ ID NO: 1; and
- (b) DNA encoding an amino acid sequence, which comprises a deletion, substitution and/or addition of one or several amino acids with respect to the amino acid sequence shown in SEQ ID NO: 1, and has light-absorbing properties.

5

[0033] Other examples of DNA encoding the chromoprotein of the present invention may include either one of the following DNAs:

- (a) the nucleotide sequence shown in SEQ ID NO: 2; and
- (b) a nucleotide sequence comprising a deletion, substitution and/or addition of one or several nucleotides with respect to the nucleotide sequence shown in SEQ ID NO: 2, and encoding a protein having light-absorbing properties.

10

[0034] The DNA of the present invention can be synthesized by, for example, the phosphoramidite method, or it can also be produced by polymerase chain reaction (PCR) using specific primers. The DNA of the present invention is produced by the method described above in the specification.

15

[0035] A method of introducing a desired mutation into a certain nucleic acid sequence is known to a person skilled in the art. For example, known techniques such as a site-directed mutagenesis, PCR using degenerated oligonucleotides, or the exposure of cells containing nucleic acid to mutagens or radioactive rays, are appropriately used, so as to construct DNA having a mutation. Such known techniques are described in, for example, Molecular Cloning: A Laboratory Manual, 2nd Ed., Cold Spring Harbor Laboratory, Cold Spring Harbor, NY., 1989; and Current Protocols in Molecular Biology, Supplements 1 to 38, John Wiley & Sons (1987-1997).

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(3) Recombinant vector of the present invention

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[0036] The DNA of the present invention can be inserted into a suitable vector and used. The type of a vector used in the present invention is not particularly limited. For example, it may be either a vector that can autonomously replicate (e.g., a plasmid, etc.), or vector that is incorporated into the genomes of host cells when it is introduced into the host cells and is then replicated together with the chromosome into which it is incorporated.

30

[0037] The vector used in the present invention is preferably an expression vector. In an expression vector, elements necessary for transcription (e.g., a promoter, etc.) are functionally ligated to the DNA of the present invention. The promoter is a DNA sequence which shows a transcriptional activity in host cells, and it is appropriately selected depending on the type of host cells.

35

[0038] Examples of a promoter which can operate in bacterial cells may include a *Bacillus stearothermophilus* maltogenic amylase gene promoter, a *Bacillus licheniformis* alpha-amylase gene promoter, a *Bacillus amyloliquefaciens* BAN amylase gene promoter, a *Bacillus subtilis* alkaline protease gene promoter, a *Bacillus pumilus* xylosidase gene promoter, P_R and P_L promoters of phage lambda, and lac, trp and tac promoters of *Escherichia coli*.

40

[0039] Examples of a promoter which can operate in mammalian cells may include an SV40 promoter, an MT-1 (metallothionein gene) promoter, and an adenovirus-2 major late promoter. Examples of a promoter which can operate in insect cells may include a polyhedrin promoter, a P10 promoter, an *Autographa californica* polyhedrosis basic protein promoter, a baculovirus immediate-early gene 1 promoter, and a baculovirus 39K delayed-early gene promoter. Examples of a promoter which can be operate in yeast host cells may include promoters derived from yeast glycolytic genes, an alcohol dehydrogenase gene promoter, a TPI1 promoter, and an ADH2-4c promoter.

45

[0040] Examples of a promoter which can operate in filamentous cells may include an ADH3 promoter and a tpiA promoter.

50

[0041] In addition, an appropriate terminator such as a human growth hormone terminator, or a TPI1 terminator or ADH3 terminator for fungal cells, may be functionally bound to the DNA of the present invention, as necessary. The recombinant vector of the present invention may further have elements such as a polyadenylation signal (e.g., one derived from SV40 or the adenovirus 5E1b region), a transcription enhancer sequence (e.g., an SV40 enhancer), or a translation enhancer sequence (e.g., one encoding the adenovirus VA RNA).

55

[0042] The recombinant vector of the present invention may further comprise a DNA sequence which enables the replication of the recombinant vector in host cells. SV40 replication origin is an example of such a sequence (when the host cells are mammalian cells).

[0043] The recombinant vector of the present invention may further comprise a selective marker. Examples of such a selective marker may include genes, complements of which are absent from host cells, such as a dihydrofolate reductase (DHFR) gene or a *Shizosaccharomyces pombe* TPI gene, and drug resistant genes such as ampicillin, kanamycin, tetracycline, chloramphenicol, neomycin or hygromycin-resistant genes.

[0044] A method for ligating the DNA of the present invention, a promoter and, as desired, a terminator and/or a

secretory signal sequence to one another and inserting these items into a suitable vector is known to a person skilled in the art.

(4) Transformant of the present invention

[0045] A transformant can be produced by introducing the DNA or recombinant vector of the present invention into a suitable host.

[0046] Any cell can be used as a host cell into which the DNA or recombinant vector of the present invention is introduced, as long as the DNA construct of the present invention can be expressed therein. Examples of such a cell may include bacteria, yeasts, fungal cells, and higher eukaryotic cells.

[0047] Examples of bacteria may include Gram-positive bacteria such as *Bacillus* or *Streptomyces*, and Gram-negative bacteria such as *Escherichia coli*. These bacteria may be transformed by the protoplast method or other known methods, using competent cells.

[0048] Examples of mammalian cells may include HEK 293 cells, HeLa cells, COS cells, BHK cells, CHL cells, and CHO cells. A method of transforming mammalian cells and expressing the introduced DNA sequence in the cells is also known. Examples of such a method may include the electroporation, the calcium phosphate method, and the lipofection method.

[0049] Examples of yeast cells may include those belonging to *Saccharomyces* or *Shizosaccharomyces*. Examples of such cells may include *Saccharomyces cerevisiae* and *Saccharomyces kluyveri*. Examples of a method of introducing a recombinant vector into yeast host cells may include the electroporation, the spheroplast method, and the lithium acetate method.

[0050] Examples of other fungal cells may include those belonging to *Filamentous fungi* such as *Aspergillus*, *Neurospora*, *Fusarium* or *Trichoderma*. Where *Filamentous fungi* are used as host cells, transformation can be carried out by incorporating DNA constructs into host chromosomes, so as to obtain recombinant host cells. Incorporation of DNA constructs into the host chromosomes is carried out by known methods, and such known methods may include homologous recombination and heterologous recombination.

[0051] Where insect cells are used as host cells, both a vector into which a recombinant gene is introduced and a baculovirus are co-introduced into insect cells, and a recombinant virus is obtained in the culture supernatant of the insect cells. Thereafter, insect cells are infected with the recombinant virus, so as to allow the cells to express proteins (described in, for example, *Baculovirus Expression Vectors, A Laboratory Manual*; and *Current Protocols in Molecular Biology*, Bio/Technology, 6, 47 (1988)).

[0052] The *Autographa californica* nuclear polyhedrosis virus, which is a virus infecting to insects belonging to *Barathra brassicae*, can be used as baculovirus.

[0053] Examples of insect cells used herein may include Sf9 and Sf21, which are *Spodoptera frugiperda* ovarian cells [*Baculovirus Expression Vectors, A Laboratory Manual*, W. H. Freeman & Company, New York, (1992)], and HiFive (manufactured by Invitrogen), which are *Trichoplusia ni* ovarian cells.

[0054] Examples of the method of co-introducing both a vector into which a recombinant gene has been introduced and the above baculovirus into insect cells to prepare a recombinant virus may include the calcium phosphate method and the lipofection method.

[0055] The above transformant is cultured in an appropriate nutritive medium under conditions enabling the introduced DNA construct to be expressed. In order to isolate and purify the protein of the present invention from the culture product of the transformant, common methods of isolating and purifying proteins may be used.

[0056] For example, where the protein of the present invention is expressed in a state dissolved in cells, after completion of the culture, cells are recovered by centrifugal separation, and the recovered cells are suspended in a water type buffer. Thereafter, the cells are disintegrated using an ultrasonic disintegrator or the like, so as to obtain a cell-free extract. A supernatant is obtained by centrifuging the cell-free extract, and then, a purified sample can be obtained from the supernatant by applying, singly or in combination, the following ordinary protein isolation and purification methods: the solvent extraction, the salting-out method using ammonium sulfate or the like, the desalting method, the precipitation method using an organic solvent, the anion exchange chromatography using resins such as diethylaminoethyl (DEAE) sepharose, the cation exchange chromatography using resins such as S-Sepharose FF (manufactured by Pharmacia), the hydrophobic chromatography using resins such as butyl sepharose or phenyl sepharose, the gel filtration method using a molecular sieve, the affinity chromatography, the chromatofocusing method, and the electrophoresis such as isoelectric focusing.

(5) Use of the chromoprotein of the present invention and a fusion protein comprising the same

[0057] The chromoprotein of the present invention can be fused with another protein, so as to construct a fusion protein. The type of said another protein to be fused to the chromoprotein of the present invention is not particularly

limited, and preferred examples may include a protein which interacts with another molecule. The examples may include a receptor protein or ligand thereof, antigen, antibody and the like.

[0058] A method of obtaining the fusion protein of the present invention is not particularly limited. It may be either a protein synthesized by chemosynthesis, or recombinant protein produced by a gene recombination technique.

5 [0059] Where a recombinant fusion protein is produced, it is necessary to obtain DNA encoding the protein. The DNA encoding the chromoprotein of the present invention and the DNA encoding the another protein to be fused to the chromoprotein, can be obtained by the method as mentioned above in this specification or by the method similar to it. Then, these DNA fragments are ligated to one another by a gene recombination technique, so that DNA encoding the desired fusion protein can be obtained. This DNA is then introduced into an appropriate expression system, so that

10 the fusion protein of the present invention can be produced.
[0060] FRET (fluorescence resonance energy transfer) has been known as a means for analyzing the interaction between molecules. In FRET, for example, a first molecule labeled with a cyan fluorescent protein (CFP) acting as a first fluorescent protein is allowed to coexist with a second molecule labeled with a yellow fluorescent protein (YFP) acting as a second fluorescent protein, so as to allow the yellow fluorescent protein (YFP) to act as an acceptor molecule and to allow the cyan fluorescent protein (CFP) to act as a donor molecule. Thus, FRET (fluorescence resonance energy transfer) is allowed to take place between both molecules, so as to visualize the interaction between the first and second molecules. Namely, in FRET, different dyes are introduced into two types of molecules. One dyes with a higher energy level (a donor molecule) is selectively excited, and the fluorescence of the dye is measured. Long-wavelength fluorescence from the other dye (an acceptor molecule) is also measured. The interaction between the molecules is visualized by using the difference between the amounts of both fluorescences. Only when both dyes are adjacent to each other due to the interaction of the two types of molecules, a decrease in the fluorescence of the donor molecule and an increase in the fluorescence of the acceptor molecule are observed by single wavelength excitation dual wavelength photometry. However, in a case where a chromoprotein is used as an acceptor molecule, a decrease in the fluorescence of the donor molecule occurs only when both dyes are adjacent to each other by the interaction of the two types of molecules. Such a decrease can be observed by single wavelength excitation single wavelength photometry. Thus, the use of the chromoprotein of the present invention enables facilitation of measurement apparatuses.

25 [0061] The chromoprotein of the present invention is particularly advantageous when it is used as an acceptor molecule in FRET (fluorescence resonance energy transfer). That is to say, a fused form (a first fused form) of the chromoprotein of the present invention and a test substance is first produced. Then, a fused form (a second fused form) of another test substance interacting with the above test substance and another fluorescent protein is produced. Thereafter, the first fused form is allowed to interact with the second fused form, and the generated fluorescence is analyzed, so that the interaction between the aforementioned two types of test substances can be analyzed. FRET (fluorescence resonance energy transfer) using the chromoprotein of the present invention may be carried out either in a test tube or in a cell.

(6) Kit of the present invention

40 [0062] The present invention provides a light-absorbing reagent kit comprising at least one which is selected from the chromoprotein, fusion protein, DNA, recombinant vector or transformant, which are described in the present specification. The kit of the present invention can be produced from commonly used materials that are known per se, by using common methods.

45 [0063] Reagents such as the chromoprotein or the DNA are dissolved in an appropriate solvent, so that the reagents can be prepared in a form suitable for conservation. Water, ethanol, various types of buffer solution, etc. can be used as such a solvent.

[0064] The present invention will be further described in the following examples. However, the present invention is not limited by these examples.

EXAMPLES

50 Example 1: Isolation of gene encoding novel chromoprotein from sea anemone

(1) Extraction of total RNA

55 [0065] A chromoprotein gene was isolated from sea anemone emitting a purple color. *Cnidopus japonicus* emitting a green color was used as a material. Frozen *Cnidopus japonicus* was crushed in a mortar. 7.5 ml of "TRIzol" (GIBCO BRL) was added to 1 g (wet weight) of *Cnidopus japonicus*, and the mixture was homogenized, followed by centrifugation at 1,500 x g for 10 minutes. 1.5 ml of chloroform was added to the supernatant. The mixture was stirred for 15

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seconds and then left at rest for 3 minutes. The resultant product was centrifuged at 7,500 x g for 15 minutes. 3.75 ml of isopropanol was added to the supernatant. The mixture was stirred for 15 seconds and then left at rest for 10 minutes. The resultant product was centrifuged at 17,000 x g for 10 minutes. The supernatant was discarded, and 6 ml of 70% ethanol was added thereto. The obtained mixture was centrifuged at 17,000 x g for 10 minutes. The supernatant was discarded, and the precipitate was dissolved in 200 µl of DEPC water. Total RNA dissolved in the DEPC water was 100 times diluted, and the values of O.D.260 and O.D.280 were measured, so as to determine the concentration of RNA. 2 mg of the total RNA was obtained from a purple individual.

(2) Synthesis of first strand cDNA

[0066] cDNA (33 µl) was synthesized from 4 µg of the total RNA using a kit for synthesizing first strand cDNA, "Ready To Go" (Amersham Pharmacia).

(3) Degenerated PCR

[0067] Using 3 µl out of the synthesized first strand cDNA (33 µl) as a template, PCR was carried out. Primers were designed and produced by comparing the amino acid sequences of known fluorescent proteins, extracting similar portions, and converting them into nucleotide sequences. The sequences of the used primers are shown below:

5'-GAAGGRTGYGTCAAYGGRCA Y-3' (primer 1) (SEQ ID NO: 3);

and

5'-ACVGGDCCATYDGVAAGAAARTT-3' (primer 2) (SEQ ID NO: 4),

wherein R represents A or G, Y represents C or T, V represents A, C or G, and D represents A, G or T.

| Composition of PCR reaction solution | |
|--------------------------------------|-------|
| Template (first strand cDNA) | 3 µl |
| X 10 taq buffer | 5 µl |
| 2.5 mM dNTPs | 4 µl |
| 100 uM primer 1 | µl |
| 100 uM primer 2 | 1 µl |
| Milli Q | 35 µl |
| Taq polymerase (5 U/µl) | 1 µl |

PCR reaction conditions

94°C, 1 minute (PAD)

94°C, 30 seconds (denaturation)

52°C, 30 seconds (annealing of the primers to the template)

72°C, 1 minute (elongation of the primers)

30 cycles consisting of the above 3 steps were carried out. The annealing temperature was decreased 0.3°C per cycle. That is to say, the annealing temperature in the 30th cycle was 43°C.

72°C, 7 minutes (final elongation)

Retention at 4°C

[0068] Using 1 µl of an amplified product obtained as a result of the first PCR reaction as a template, PCR was carried out once again under the same conditions. A 350-bp fragment (derived from the purple individual) was cut out by agarose gel electrophoresis and then purified.

(4) Subcloning and sequencing

[0069] The purified DNA fragment was ligated to a pT7-blue vector (Novagen). *Escherichia coli* (TG1) was trans-

formed with the vector, and the obtained transformants were subjected to blue white selection. Thereafter, plasmid DNA was purified from white colonies of *Escherichia coli*. The nucleotide sequence of the inserted DNA fragment was determined by a DNA sequencer. The obtained nucleotide sequence was compared with the nucleotide sequences of other fluorescent protein genes to confirm that the nucleotide sequence of the DNA was derived from a fluorescent protein. 5'-RACE and 3'-RACE methods were applied to a gene that had been confirmed to be a part of a fluorescent protein gene, so as to carry out the cloning of a full-length gene.

(5) 5'-RACE method

[0070] In order to determine the nucleotide sequence of the 5'-terminal side of the DNA fragment obtained by degenerated PCR, the 5'-RACE method was applied using 5'-RACE System for Rapid Amplification of cDNA Ends, Version 2.0 (GIBCO BRL). 3 µg of the total RNA prepared in (1) above was used as a template.

[0071] For the first amplification of DC-tailed cDNA of the purple individual, the following primers were used:

5'-GGCCACGCGTCGACTAGTACGGGIIIGGGIIGGGIIG-3' (primer 3) (SEQ ID NO: 5);

and

5'-ATAGATCAGGCAATCTCCC-3' (primer 4) (SEQ ID NO: 6),

wherein I represents inosine.

[0072] For the second amplification, the following primers were used:

5'-GGCCACGCGTCGACTAGTAC-3' (primer 5) (SEQ ID NO: 7);

and

5'-GGTGAGCTGTGAGGTGACCA-3' (primer 6) (SEQ ID NO: 8).

PCR reaction conditions and the like were determined in accordance with the protocols attached with the kit.

[0073] The 450-bp amplified band was cut out by agarose gel electrophoresis and then purified. The purified DNA fragment was ligated to a pT7-blue vector (Novagen). *Escherichia coli* (TG1) was transformed with the vector, and the obtained transformants were subjected to blue white selection. Thereafter, plasmid DNA was purified from white colonies of *Escherichia coli*. The nucleotide sequence of the inserted DNA fragment was determined by a DNA sequencer.

(6) 3'-RACE method

[0074] The 3'-terminal portion of the DNA fragment obtained by degenerated PCR was obtained by PCR, using primers shown below, that are, primers 7 and 8 produced based on the information obtained by sequencing of the nucleotide sequence in (4) above. 3 µl of the first strand cDNA prepared in (2) above was used as a template. The used primers are shown below:

5'-CACCGAAGGCGGGCCATTGC-3' (primer 7) (SEQ ID NO: 9);

and

5'-AACTGGAAGAATTCGCGGCCGCAGAATTTTTTTTTTTTTTTTTT-3' (primer 8)

(SEQ ID NO: 10).

| Composition of PCR reaction solution | |
|--------------------------------------|-------|
| Template (first strand cDNA) | 3 µl |
| X 10 taq buffer | 5 µl |
| 2.5 mM dNTPs | 4 µl |
| 20 µM primer 7 | 1 µl |
| 10 µM primer 8 | 1 µl |
| Milli Q | 35 µl |
| Taq polymerase (5 U/µl) | 1 µl |

PCR reaction conditions

94°C, 1 minute (PAD)

94°C, 30 seconds (denaturation)

55°C, 30 seconds (annealing of the primers to the template)

72°C, 1 minute (elongation of the primers)

30 cycles consisting of the above 3 steps were carried out.

72°C, 7 minutes (final elongation)

Retention at 4°C

[0075] An amplified band of approximately 1,200 bp was cut out by agarose gel electrophoresis and then purified. The purified DNA fragment was ligated to a pT7-blue vector (Novagen). *Escherichia coli* (TG1) was transformed with the vector, and the obtained transformants were subjected to blue white selection. Thereafter, plasmid DNA was purified from white colonies of *Escherichia coli*. The nucleotide sequence of the inserted DNA fragment was determined by a DNA sequencer. The obtained full-length nucleotide sequence is shown in SEQ ID NO: 2, and the obtained full-length amino acid sequence is shown in SEQ ID NO: 1.

Example 2: Expression of protein in *Escherichia coli*

[0076] Primers corresponding to the N- and C-termini of the protein were produced from the full-length nucleotide sequence obtained Example 1. PCR was carried out using the primers and the first strand cDNA prepared in (2) above as a template. The used primers are as follows:

5'-CGGGATCCGACCATGGCTTCAATGATTAAAG-3' (primer 9) (SEQ ID NO: 11);

and

5'-CCGGAATTCTTAGTGCTTTGACGGGGCAACATC-3' (primer 10) (SEQ ID NO: 12).

| Composition of PCR reaction solution | |
|--------------------------------------|------|
| Template (first strand cDNA) | 3 µl |
| X 10 pyrobest buffer | 5 µl |
| 2.5 mM dNTPs | 4 µl |
| 100 µM primer 9 | 1 µl |
| 100 µM primer 10 | 1 µl |

(continued)

| Composition of PCR reaction solution | |
|--------------------------------------|------------|
| Milli Q | 35 μ l |
| Pyrobest polymerase (5 U/ μ l) | 1 μ l |

RCR reaction conditions

94°C, 1 minute (PAD)

94°C, 30 seconds (denaturation)

55°C, 30 seconds (annealing of the primers to the template)

72°C, 1 minute (elongation of the primers)

30 cycles consisting of the above 3 steps were carried out.

72°C, 7 minutes (final elongation)

Retention at 4°C

[0077] An amplified band of approximately 700 bp was cut out by agarose gel electrophoresis and then purified. The purified DNA fragment was subcloned into the *Bam*HI-*Eco*RI site of a pRSET vector (Invitrogen), and it was then allowed to express in *Escherichia coli* (JM109-DE3). Since the expressed protein was constructed such that His-tag was attached to the N-terminus thereof, it was purified with Ni-Agarose gel (QIAGEN). Purification was carried out in accordance with the attached protocols.

Example 3: Analysis of protein

(1) Analysis of light-absorbing properties

[0078] The light-absorbing properties of the protein expressed in Example 2 were analyzed.

[0079] An absorption spectrum was measured using a 50 mM HEPES solution (pH 7.5) containing a 20 μ M chromoprotein. A molar absorption coefficient was calculated from the peak value of this spectrum. In the case of the chromoprotein derived from the purple individual (referred to as KP), the absorption peak was observed at 559 nm (Table 1, Figure 1). KP showed extremely weak fluorescence having a peak of 578nm.

Table 1

| Properties of chromoprotein (KP) | | | | | |
|----------------------------------|----------------------|------------------------------|---------------|----------------|-----------------------|
| Absorption maximum | Fluorescence maximum | Molar absorption coefficient | quantum yield | pH sensitivity | Number of amino acids |
| 559 nm | 578 nm | 61,150 (559 nm) | 0.01> | Non | 229 |

(1) Measurement of pH sensitivity

[0080] The pH sensitivity of the protein expressed in Example 2 was analyzed.

[0081] The absorption spectrum of the protein was measured in the following 100 mM buffer solution (Figure 2). The following buffer solutions were used for each pH:

pH 4 and 5: Acetate buffer

pH 6: MES buffer

pH 7 and 8: HEPES buffer

pH 9 and 10: Glycine buffer

[0082] The peak value did not significantly change at any pH.

INDUSTRIAL APPLICABILITY

[0083] The present invention provides a novel chromoprotein derived from *Cnidopus japonicus*. The chromoprotein of the present invention has desired fluorescence properties and low pH sensitivity. Thus, it is useful for molecular biology analysis.

SEQUENCE LISTING

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30

20 25 30

Lys Pro Tyr Glu Gly Thr Gln Leu Gly Arg Ile Arg Val Thr Glu Gly

35

35 40 45

Gly Pro Leu Pro Phe Ser Phe Asp Ile Leu Ser Thr Cys Thr Gln Tyr

50 55 60

40

Gly Ser Lys Thr Met Ile Lys His Leu Ser Gly Ile Pro Asp Tyr Phe

65 70 75 80

45

Lys Gln Ser Phe Pro Glu Gly Phe Thr Trp Glu Arg Asn Thr Ile Tyr

85 90 95

Glu Asp Gly Gly His Leu Thr Ala His Gln Asp Thr Ser Leu Lys Gly

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100 105 110

Asp Cys Leu Ile Tyr Lys Val Lys Val Leu Gly Gly Asn Phe Pro Ala

55

115 120 125

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 145 150 155 160
 10 Ala Leu Lys Cys Ala Asn Gly Lys Asn Leu Thr Cys Gln Leu Arg Ser
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 15 Thr Tyr Arg Ser Arg Lys Gln Ala Ser Ala Leu Gln Thr Pro Gly Phe
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ccggaattct tagtgctttg acggggcaac atc 33

Claims

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1. A chromoprotein derived from *Cnidopus japonicus* having the following properties:

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- (1) the absorption maximum wavelength is 559 nm and the fluorescence maximum wavelength is of 578 nm;
- (2) the molar absorption coefficient is 61,150 at 559 nm;
- (3) the quantum yield is less than 0.01; and
- (4) the pH sensitivity of light-absorbing properties is stable at between pH 4 and pH 10.

2. A chromoprotein having either one of the following amino acid sequences:

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- (a) the amino acid sequence shown in SEQ ID NO: 1; and
- (b) an amino acid sequence comprising a deletion, substitution and/or addition of one or several amino acids with respect to the amino acid sequence shown in SEQ ID NO: 1, and having light-absorbing properties.

5 3. A DNA encoding the protein of claim 1 or 2.

4. A DNA of either one of followings:

- (a) DNA encoding the amino acid sequence shown in SEQ ID NO: 1; and
- 10 (b) DNA encoding an amino acid sequence, which comprises a deletion, substitution and/or addition of one or several amino acids with respect to the amino acid sequence shown in SEQ ID NO: 1, and has light-absorbing properties.

15 5. A DNA having either one of the following nucleotide sequences:

- (a) the nucleotide sequence shown in SEQ ID NO: 2; and
- (b) a nucleotide sequence comprising a deletion, substitution and/or addition of one or several nucleotides with respect to the nucleotide sequence shown in SEQ ID NO: 2, and encoding a protein having light-absorbing properties.

20 6. A recombinant vector having the DNA of claim 4 or 5.

7. A transformant having the DNA of claim 4 or 5 or the recombinant vector of claim 6.

25 8. A fusion protein composed of the chromoprotein of claim 1 or 2 and another protein.

9. A method for analyzing a physiologically active substance, which is **characterized in that** the FRET (fluorescence resonance energy transfer) method is applied using the chromoprotein of claim 1 or 2 as an acceptor protein.

30 10. A light-absorbing reagent kit comprising the chromoprotein of claim 1 or 2, the DNA of any of claims 3 to 5, the recombinant vector of claim 6, the transformant of claim 7, or the fusion protein of claim 8.

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Fig. 1

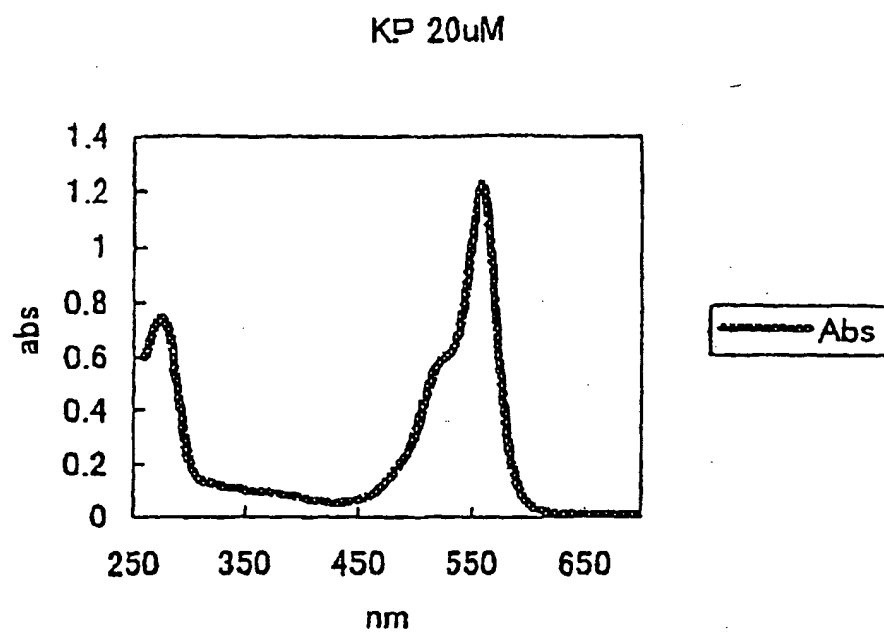


Fig. 2

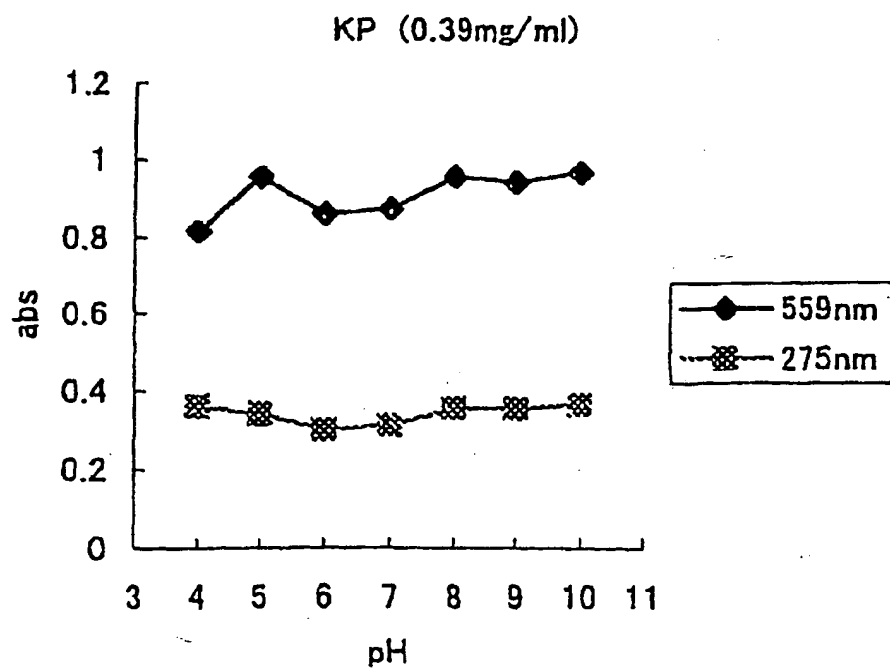
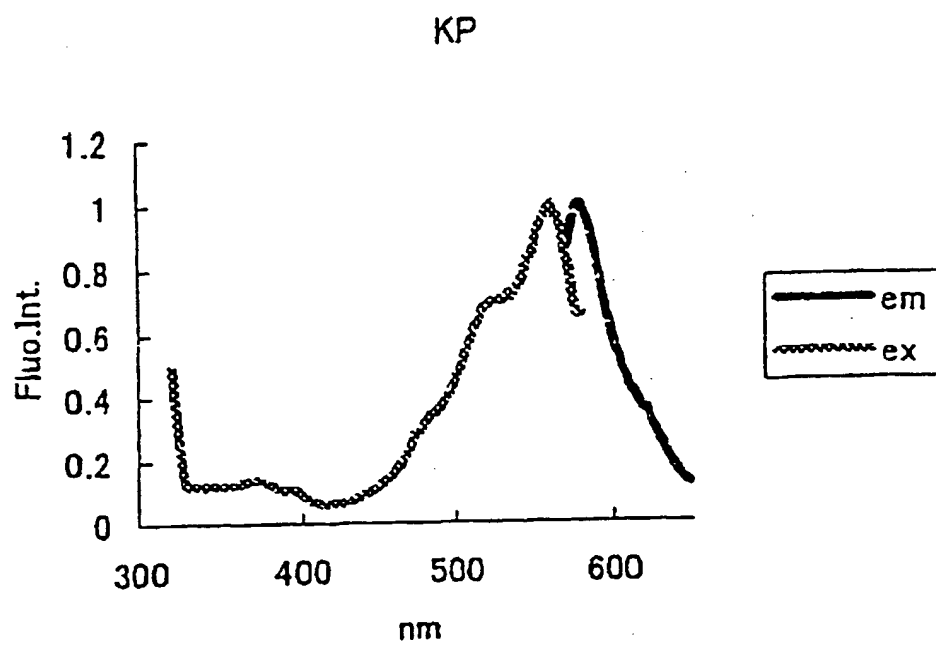


Fig. 3



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP03/07337

| A. CLASSIFICATION OF SUBJECT MATTER Int.Cl ⁷ C12N15/12, 1/21, 5/10, C07K14/435, 19/00, G01N21/78 | | | | | | | | | | | | | | |
|---|---|--|-----------|--|-----------------------|---|---|------|---|---|------|---|--|------|
| According to International Patent Classification (IPC) or to both national classification and IPC | | | | | | | | | | | | | | |
| B. FIELDS SEARCHED Minimum documentation searched (classification system followed by classification symbols) Int.Cl ⁷ C12N15/00-15/90, 1/21, 5/10, C07K14/00-14/825, 19/00, G01N21/78 | | | | | | | | | | | | | | |
| Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched | | | | | | | | | | | | | | |
| Electronic data base consulted during the international search (name of data base and, where practicable, search terms used) MEDLINE (STN), WPI/BIOSIS (DIALOG), JSTPlus (JOIS) GenBank/EMBL/DBJ/GeneSeq, SwissProt/PIR/GeneSeq | | | | | | | | | | | | | | |
| C. DOCUMENTS CONSIDERED TO BE RELEVANT <table border="1"> <thead> <tr> <th>Category*</th> <th>Citation of document, with indication, where appropriate, of the relevant passages</th> <th>Relevant to claim No.</th> </tr> </thead> <tbody> <tr> <td>X</td> <td>Atsushi MIYAWAKI, "Shiho Dobutsu to Keiko Tanpaku-Shitsu", Midoriishi, March, 2002, No.13, pages 1 to 4</td> <td>1-10</td> </tr> <tr> <td>A</td> <td>WO 00/34319 A1 (CLONTECH LABORATORIES INC.), 15 June, 2000 (15.06.00), (Family: none)</td> <td>1-10</td> </tr> <tr> <td>A</td> <td>WO 00/34526 A1 (CLONTECH LABORATORIES INC.), 15 June, 2000 (15.06.00), & EP 1135532 A1</td> <td>1-10</td> </tr> </tbody> </table> | | | Category* | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. | X | Atsushi MIYAWAKI, "Shiho Dobutsu to Keiko Tanpaku-Shitsu", Midoriishi, March, 2002, No.13, pages 1 to 4 | 1-10 | A | WO 00/34319 A1 (CLONTECH LABORATORIES INC.), 15 June, 2000 (15.06.00), (Family: none) | 1-10 | A | WO 00/34526 A1 (CLONTECH LABORATORIES INC.), 15 June, 2000 (15.06.00), & EP 1135532 A1 | 1-10 |
| Category* | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. | | | | | | | | | | | | |
| X | Atsushi MIYAWAKI, "Shiho Dobutsu to Keiko Tanpaku-Shitsu", Midoriishi, March, 2002, No.13, pages 1 to 4 | 1-10 | | | | | | | | | | | | |
| A | WO 00/34319 A1 (CLONTECH LABORATORIES INC.), 15 June, 2000 (15.06.00), (Family: none) | 1-10 | | | | | | | | | | | | |
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| <input type="checkbox"/> Further documents are listed in the continuation of Box C. <input type="checkbox"/> See patent family annex. | | | | | | | | | | | | | | |
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| Date of the actual completion of the international search 27 June, 2003 (27.06.03) | | Date of mailing of the international search report 15 July, 2003 (15.07.03) | | | | | | | | | | | | |
| Name and mailing address of the ISA/ Japanese Patent Office | | Authorized officer | | | | | | | | | | | | |
| Facsimile No. | | Telephone No. | | | | | | | | | | | | |

Form PCT/ISA/210 (second sheet) (July 1998)